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ULTRA SHORT DURATION FLASH RADIOGRAPHS

by

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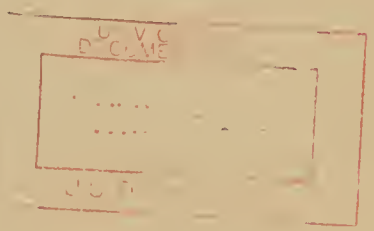

ABSTRACT

Ultra Short Duration Flash Radiographs

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The duration and nature of the bursts of x-rays produced by the high speed flash radiographic equipment described by Slack and Ehrke[1] have been studied by radiographing a very thin strip of lead cemented to a piece of explosive of high detonation velocity as the detonation proceeds. Such radiographs show that bursts of x-rays varying in duration between 1 and 3 microseconds are produced and that they are, in general, multiple in character, indicating an interrupted or oscillatory type of discharge through the x-ray tube.

For many purposes a single burst of x-rays of much shorter duration is desirable. By studying the method of initiation of a cold cathode, Slack type tube, a circuit has been assembled which operates satisfactorily at relatively low voltages (60-100 KV), producing a single x-ray burst of duration 10^{-7} sec., as measured by the same timing method.

[1] Slack and Ehrke, J.A.P., 12, 165, 1941

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The Westinghouse flash radiographic equipment is described in principle in a report by C. M. Slack and L. F. Ehrke[1]. This equipment utilizes a high vacuum cold cathode field emission type x-ray tube and a surge generator of the conventional circuit design for producing tube potentials of the order of 350 KV. The tube also contains a third electrode, called the initiating electrode, which is part of the cathode assembly. To initiate the discharge through the x-ray tube a high potential is established between the initiating electrode and the tube cathode. Presumably a metallic arc is thus established and from this arc electrons are drawn to the target of the tube. The entire circuit is arranged so that the discharge which results through the x-ray tube exists only as long as any charge remains on the capacitors in the surge generator circuit. With this equipment, flash radiographs have been made and widely published of such things as machinery in motion, rifle bullets in the barrel and in free flight, and the fragmentation patterns resulting from high explosive loaded shells during detonation.

It had earlier been determined by measurements of the radiographs of such objects as rifle bullets in flight that the duration of the x-ray discharge produced by Slack's equipment was of the order of one microsecond, but little information could be obtained from these radiographs about the nature of the x-ray burst. Extremely fast-response type ionization chambers and associated electronic circuits which could be used for analyzing the characteristics of the x-ray burst of the kind produced by this equipment are in themselves a major research project, and a much simpler and more direct method has been adopted. This consists in radiographing a very thin foil indicator strip cemented along the top of a small piece of explosive of high detonation velocity as the detonation proceeds along the piece of explosive. The radiograph thus obtained furnished direct evidence of all of the characteristics of the x-ray burst except the effective wave length of the x-rays, and such a determination can be made with the well known step wedge filter technique.

Figure 1 is a flash radiograph made by using the above technique of a 2 mil thick, 3/32" wide lead foil, securely cemented with Duco

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1 Slack and Ehrke, J. A. P., 12 165. 1941

cement to the explosive, with the detonation proceeding from left to right at approximately 7.5 mm per microsecond. It will be seen that the x-ray discharge in this case consists of several bursts of variable intensity, variable duration and lasting over two microseconds. This intermittant type of discharge is characteristic of the Westinghouse microflash equipment. It is seen that the electrical energy stored in the capacitor of the circuit is not being utilized to the best advantage for producing a single x-ray burst, preferably of duration much less than the average of two microseconds. It appears that insufficient energy in the initiation of the discharge does not make it possible for all of the stored electrical energy in the power circuit to dissipate itself through the tube in a single flash, but that it acts only to start the discharge phenomena.

A circuit has been assembled for use with the same type of x-ray tube which, in principle, produces sufficient electrons in the initiation process to allow the main capacitor of the circuit to discharge completely in a single burst, as well as in a time lasting no more than 1/10 microsecond. Consider the circuit shown in Figure 2.

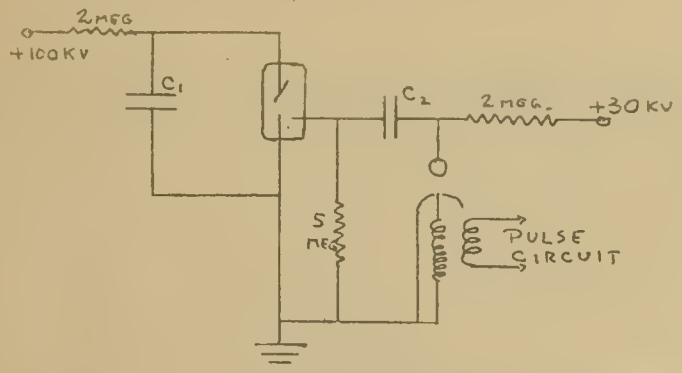

FIG. 2

If C_1 is made .04 mfd. and the charging potential 80 KV, then the average current which must flow through the tube to discharge completely the capacitor in 10^{-7} sec. is 32000 amperes, and this means that 2×10^{16} electrons must be provided for this discharge regardless of the method of initiation. When the output of the pulsing circuit is applied directly to the initiator electrode of the x-ray tube, an x-ray burst similar to that shown in Figure 1 results. However, by using the additional energy made available by an auxilliary capacitor C_2 any (reasonable) amount of energy

can be applied for the initiation, provided, of course, the discharge of this initiation circuit is made to take place within the time limit of 1/10 microsecond. The potential which must be applied to the initiator electrodes depends upon the spacing of the electrodes in the cathode assembly. For high vacuum breakdown between sharp-edged electrodes this is relatively high, even for small distances of separation. Actually, each tube which is used must be tested for minimum breakdown potential between the initiation electrodes, and at least this potential applied to the capacitor C_2. For several standard flash radiographic tubes manufactured by Westinghouse, minimum initiation potentials of 20-25 KV must be used.

With the arrangement shown in Figure 2 and with care being given to the arrangement of the circuit to minimize the impedances of the various components, flash radiographs similar to that shown in Figure 3 are obtained, wherein the single x-ray burst had a duration of no longer than 10^{-7} seconds.

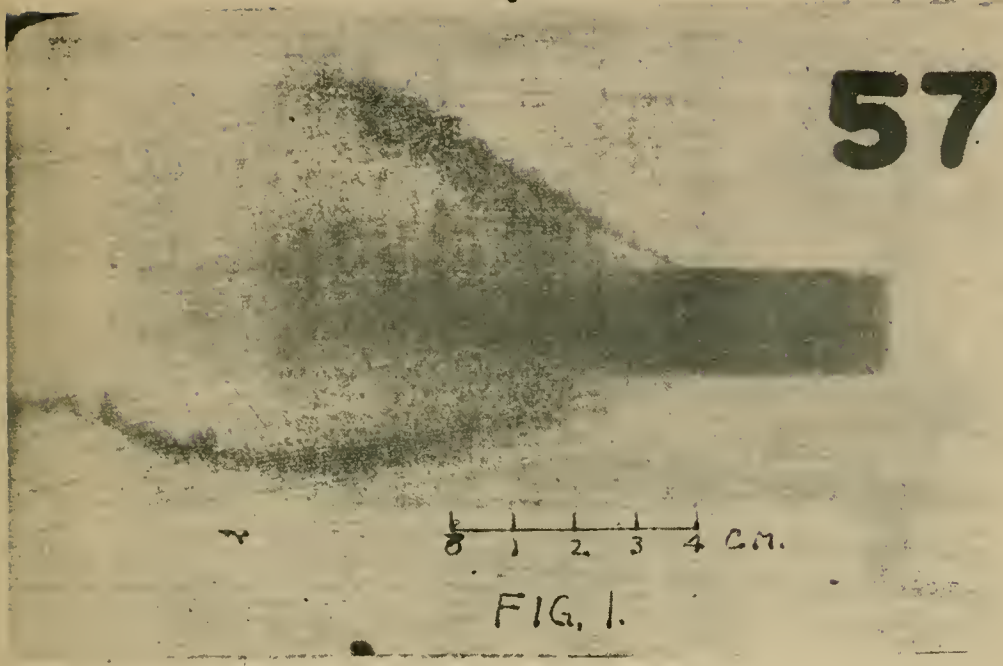

FIG. 1.

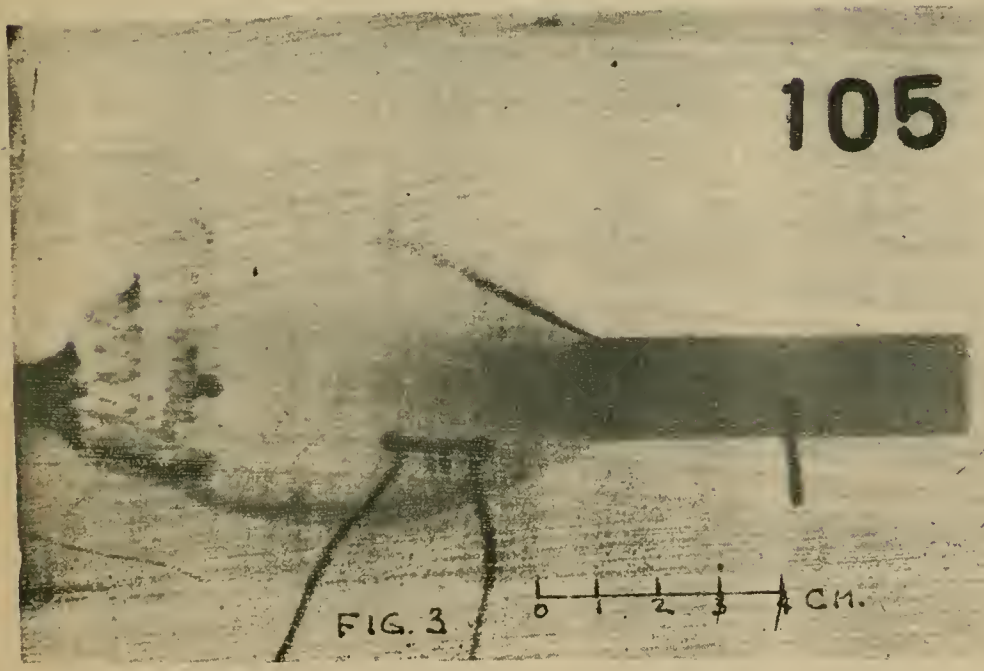

FIG. 3

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